Chapter 5. Edible Rendering--
Rendered Products for Human Use

In "Essential Rendering"

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Summary

This chapter focuses on animal by products used directly by humans. Preliminary information on world and U.S. meat and by-product production is discussed. The main products focused upon are fats and oils and their properties, animal by-products that are harvested from the carcass and cooked by the consumer or incorporated into consumable food items. Also discussed is gelatin extraction, edible tissue separated from bone, and medical and pharmaceutical products for human treatment. Where appropriate, references are given where more detailed information is available.

Definitions are important to this industry and some of the critical ones to edible animal by-products are:

Batch cooker – Horizontal, steam-jacketed cylinder with a mechanical agitator

Centrifuge – Machine using centrifugal force to separate materials of different densities

Chitlings - Small intestines of hogs

Continuous cooker – The flow of material through the system is constant

Cracklings – Solid protein material from screw press or cooking of pork fat after removal of lard

Dry rendering – Releasing fat by dehydration

Edible – Products for human consumption which is under the inspection of USDA/FSIS (for meat items in the U.S.)

Giblets – Consists of the neck, liver, heart, and gizzard of poultry

Grease – Fats with lower melting points, softer. Titer less than 40ºC

Lard (grease) – Fat from hogs (porcine), softer t than fat from ruminants

Rendering – Fatty or oil materials in meat is melted away or cooked from the solid portion of the animal tissue

Tallow – Fat from beef (bovine), mutton (ovine), goat (capra), camel (camelus), llama (lama), deer (cervidae). Higher melting point than from non-ruminants, increased hardness, Titer of 40°C or higher

Tankage – Cooked material after most of the liquid fat has been removed

Titer – Determined by melt point (ºC) test which also measures hardness

In 2004, world meat production was 253.6 million tons, and this increases every year, according to the Department of Food and Agriculture Administration of the United Nations. Approximately 40% of a live beef animal weight is processed through a rendering plant. The typical beef fat trimmings from a USDA plant consist of 60 to 64% fat, 14 to16% moisture and 20 to 24% proteins solids (Franco and Swanson, 1996). It has been estimated that nearly 50 billion pounds of by-products are generated in the U.S.A. each year when cattle, hogs, sheep, and poultry are processed. On average, slaughter houses, packing plants, supermarkets, butcher shops, and restaurants collectively generate at least 40,000 metric tonnes of animal by-product each week. Edible oil by-products utilization in the U.S. can be found in Table 1.

Table 1. Production and consumption of rendered products in U.S.

Product, million pounds	Produced	Domestic consumption	Export
Edible Tallow, 1994	1513	557	295
Lard, 1994	559	422	139

Does not total due to other uses.
Modified from Franco and Swanson, 1996.

Fat is non-uniformly stored in various areas of the animal and the quantity depends primarily on the nutrition of the animal. The fat cell has a cell wall and a nucleus located next to the cell wall; however, most of the area is composed of triglycerides. Triglycerides from both animal and plant sources are constructed of glycerol which is ester linked to three fatty acids. These three fatty acids are usually different for each triglyceride, and triglycerides are usually different for different locations in the animal. This difference continues between species with ruminant fat being quite different from non-ruminant fat. For non-ruminants, the depot fat can also be influenced by the type of fat consumed. The major difference in the triglycerides is in the fatty acids that are attached; they can be different in saturation which also influences acceptability to chemical reactions and the fatty acid chains can be of different lengths.

Edible tallow and lard are used in oleomargarine (margarine), shortening, and cooking fats. The latter two have the greatest market share. Many cooks insist that tallow gives a better flavor to fried foods than vegetable oils.

The discovery of BSE has caused the animal industry to rethink the virtue of recycling animal by-products. It is postulated that feeding cattle with byproduct meals made from other affected ruminants, and sheep with scrapie or cattle with BSE, is the primary means by which BSE is spread. "Research evidence suggests that this is the primary, if not in fact the only, means by which BSE is spread from animal to animal," was stated by Dr. Ron DeHaven, deputy administrator of veterinary services for APHIS. The practice of feeding meat and bone meal derived from ruminants back to ruminants was discontinued in the USA in 1997. However, in the U.S. meat and bone meal from ruminants may still be fed to monogastric food animals, like swine and poultry. Ruminant by-product meal is no longer used in swine and poultry feeds in EU countries and there are groups calling for this type of ban in the U.S.

An edible rendering process is usually continuous and consists of two stages of centrifugal separation. Fresh fat trimmings are usually ground through a Weiler grinder and moved by a belt to a jacket steam-heated melt tank that contains an agitator. The 110ºF (43°C) melted fat is pumped to a Reitz disintegrator to rupture the fat cells. A Sharples Super-D-Canter Centrifuge is used next and separates the fat and moisture, and also contains some solids from the fines. The fat fraction is then heated to 200°F (93ºC) by steam in a shell-and-tube heat exchanger. A second-stage centrifuge is used to polish the edible fat. This centrifuge discharges the protein fines as sludge. The edible tallow or lard, determined by the species of raw material, is then pumped into storage. The sludge is used in inedible rendering or goes into the primary treatment system for waste water.

In contrast, inedible rendering uses wet and dry rendering systems. The wet system exposes raw material to hot water (180 to 205°F, 82 to 96ºC) which later has to be evaporated. This technique results in fat, sticky water (containing glue) and wet tankage (protein solids). This system is not very energy efficient, detrimental to fat quality, and no longer used in the U.S. However, a continuous variable of this procedure is used to produce edible products. The dry rendering system works by dehydrating (240 to 280°F, 115 to 140°C) raw material with a batch or continuous cooker. It is no longer approved for edible grade fats by the USDA. The final temperature in the batch cooker varies from 250 to 275ºF (121° to 135ºC) and usually requires two to three hours of cooking time. After cooking, the product is drained, the solids are pressed (screw press or twin screw press), so the fat content is reduced from 25% to approximately 10%. The solids are then known as cracklings. The fat from pressing usually contains some fines that are removed by centrifuging or filtration. The continuous rendering system is really continuous cooking with raw material fed into one end of the cooker and cooked material discharged from the other end. The continuous system has higher capacity, occupies less space, and is more energy efficient. Other rendering processes would include ring dryers, steam tube rotary dryers, and pressure cooking.

Few cooking vapors are emitted from the two centrifuge methods for rendering edible fat. Since heat contact with the fat is minimal, fresh raw material is used and sanitation and housekeeping have to be approved in a HACCP program audited by the USDA/FSIS.

The animal product consumed as human food that comes the closest to paralleling the classical definition of rendering is lard and tallow since heat is used to separate these lipids from the muscle and bone tissue. Tallow acid consumption has been steadily increasing with valleys in depression times and peaks as the economy increases. The fast food industry in the 1990's switched from tallow and lard for frying potatoes to vegetable oil and was led by McDonalds due to public concern about animal fats, cholesterol, and heat disease.

Lard is defined as fat from hogs that is melted and strained from the cell wall tissues that encase it. The highest grade of lard is leaf lard and that is obtained from the fat around the kidneys. The next grade is from back fat and the poorest is from fat covering the small intestines. Lard is also classified by the method of preparation such as prime steam, rendered in a closed vessel into which steam is injected; neutral, melted at low temperature; kettle-rendered, heated with water added into steam-jacketed kettles; and dry-rendered, which is hashed and then heated in cookers equipped with agitators. Good lard melts quickly and is free from disagreeable odor. Pure lard (99% fat) is highly valued as cooking oil because it smokes very little when heated.

Unprocessed lard often has a strong flavor and a soft texture, but lard can be processed in many ways including separating it from the surrounding tissue by heat, filtering, bleaching, and hydrogenation. In general, processed lard is firmer (about the consistency of vegetable shortening), has a milder, more nutlike flavor and a longer shelf life than vegetable oils. Lard produces extremely tender, flaky biscuits and pastries. It's also a flavorful fat for frying. When substituting lard for butter or vegetable oils in baking, reduce the amount by 20 to 25 percent. All lard should be tightly wrapped to prevent absorption of other flavors that may be present in the storage area. It may be stored at room temperature or in the refrigerator depending on how it has been processed. Lard (often with a needle) is also used to insert long, thin strips of fat (usually pork) or bacon into dry cuts of meat. The purpose of larding is to make the cooked meat more succulent, tender, and flavorful. These strips are commonly referred to as lardons. The un-hydrogenated fatty acid composition of edible fats and oils can be located in Table 2. Fats and oils from both animals and plants are composed of triglycerides which are three fatty acids connected to glycerol by an ester linkage. The only difference in triglycerides is the degree of unsaturation (double bonds in the fatty acids) and the fatty acid chain length. The quality of an edible fat is judged by titre, free fatty acid (FFA), FAC (Fat Analysis Committee of the American Oil Chemists Society) color or Lovibond color, moisture impurities (insoluble), and unsaponifable matter (MIU).

Titre determines the hardness or softness of the fat or the temperature at which it will solidify. The more unsaturated the fat the lower will be the titer. Also, shorter the chain length of the fatty acids, the lower the titer. This will vary with species. For example, cattle and sheep fat will have a higher titre and pork fat will have a lower titre. For example, the solidification ranges of fats of different species are:

Sheep	111 to 118°F (44 to 48ºC)
Beef	108 to 113°F (42 to 45ºC)
Pork	97 to 104°F (36 to 40ºC)

This temperature difference is important when making an emulsified sausage product since the chopping temperature must be modified depending on the species and the titre used for the fat incorporated into the sausage.

Within each species, the titre will also be different depending on the location of the fat within the carcass. For example, the titre is higher for kidney fat compared to loin fat. For a nonruminant animal, the diet can also influence the hardness of the fat. For example, a pig fed on peanuts has a lower solidification point than pigs fed on corn. Well-fed animals will also have a higher titre than fat from emaciated animals.

Free Fatty Acids (FFA) are usually expressed as the percentage of oleic acid of total sample weight. The free fatty acids is caused by breaking of the ester linkage and liberating the fatty acid from the triglyceride. This is undesirable and an indication of degree of spoilage that has occurred. To keep FFA as low as possible, it is necessary to use clan raw material, clean equipment, control temperature to below 20°C or above 65ºC (to inactivate bacteria and enzymes), keep raw material whole as long as possible (reduce surface area), rapid handling, and control temperature and pressure during rendering and storage. Acceptable quality FFA should usually be less than 2%.

Color of fat can be almost white to yellow and often shades of green, brown or red are observed. The causes of color differences can often be explained by green coming from contact with intestinal content containing chlorophyll, rendering overheating will often result in reddish color, and contaminated with blood will often result in a brown color. Color of raw material can also be influenced by breed (channel island cattle often have yellow fat), feed, age(older animals sometimes have yellow fat) , and condition of the animal. To reduce color problems, raw material should be fresh, clean, and free of contamination. Blood and intestinal content should not be in the cooker and temperature and pressure must be appropriately controlled.

Moisture is undesirable in fat, since it will encourage bacterial growth and fat-splitting enzymes. Moisture is expressed as parts per hundred and levels of 0.2% are usually acceptable. Areas that will help in maintaining low moisture levels would include draining of moisture from raw material (using cool temperature as necessary), avoid ineffective use of water in the settling process, drain water from settling and appropriate storage containers Also, condensation must be avoided.

Impurities (Insoluble) are undesirable and may originate from non-fatty material (5-19%) in the trimmed fat. Foreign material such as protein fines, bone powder, hair, and manure are sometimes found in fat. Some of these can be removed by settling or centrifugation and others may be removed by filtration. Some of the colloidal fines, or ones that are soluble in the fat, are often difficult to remove.

Impurities (fat soluble) are undesirable and often consist of copper, tin (from brass), and zinc. Polyethylene is a problem since it melts during processing burns on the heater coils, or dissolves in the tallow. It will normally settle. Even in inedible products, a maximum of 50ppm is the upper acceptable limit. Steps to help reduce this problem would include, clean raw material, proper settling and filtration. Do not use pipes or valves which contain brass or copper or zinc, monitor raw materials for polyethylene and other contaminants, and filter aids may also be helpful.

Unsaponifiable Matter is the portion of the lipid fraction that will not saponify when an alkali is added. Triglycerides (the major quantity of the fat) will saponify; therefore, the addition of an alkali divides the lipid fraction into two categories. Both fractions are a nonpolar soluble, but the small nonsaponifiable fraction is chemically quite different from the saponifiable triglycerides. An example of a natural unsaponifiable material would be cholesterol; however, an example of mineral unsafonifiable material would be lubricating oils and greases from pumps and machinery. Good maintenance can reduce the mineral unsaponifiable from downgrading the fat.

Bleachability is a color test using activated clay and a color measuring instrument. High temperatures will fix color in tallow. Therefore, this test is a good indication of temperature and handling condition to which the fat has been exposed. The cleaner the raw material and the lower the temperatures and pressure used, will result in a lighter bleach value.

Other tests that indicate the quality of the fat would include saponification number (the higher the number the shorter the average fatty acid chain length), iodine value (the lower the number the less double bonds or unsaturation), peroxide number (a measure of oxidation or rancidity that has occurred) and fresh fat should have values of 1-2. TBA or TBARS (another measure of oxidation or rancidity that has occurred), and smoke point (correlated to flash and fire point and will indicate the temperatures where these reactions will occur). Smoke points are also directly correlated to the quantity of free fatty acids. To reduce oxidation and rancidity, pumping and storage should minimize air incorporation and foaming, not mixing old and new fat, and the use of antioxidants.

Table 2. Chemical Composition of Animal Fats

Carbon Chain Length (first number) and Unsaturation (number after C is the number of double bonds)	Tallow, Beef	Lard, Hog	Poultry, Fat
^{12}C Lauric			0.5
^{14}C Myristic	3.0	1.5	1.5
^{15}C Pentadecanoic	0.5		
^{16}C Palmitic	24	27	22.5
^{16}C 1=Palmitoleic	2.5	3	8.5
^{17}C Margaric	1.5	0.5	
^{18}C Stearic	20	13.5	5.5
^{18}C 1=Oleic	43	43.5	40
^{18}C 2=Linoleic	4	10.5	19
^{18}C 3=Linolenic	0.3	0.5	1
^{20}C Arachadic	0.5		
Iodine Value[a]	48	65	90
Saponification[b]	200	200	196
Titer C-fatty acid[c] basis	43	36	32

[a] Higher the number the more unsaturated fatty acids.
[b] Higher the number the shorter the fatty acid chain length.
[c] Higher the number the higher the melting point or the harder the fat.
Modified from: Franco and Swanson, 1996; Ockerman, 1996

Many other parts of the carcass don't quite fit the high temperature rendering definition but are by-products of the animal industry and are consumed by humans. These vary tremendously by who and how they are used, and their nutritional quality. The quantity available can be found in Table 3.

Table 3. By-product yield based on live weight.

	Percentage of live weight			
	Beef	Hog (pig)	Lamb	Chicken [1.4-2.3 kg (3-5 lb)]
Cheeks	0.32			
Blood	2.4—6	2—6	4—9	
Blood, dried	0.7			
Brain	0.08—0.1	0.08—0.1	0.26	0.2—0.3
Chitlings	0.06			
Cracklings	3.0	2.2		
Edible kill fat	1—7	1.3—3.5	12	
Feet	1.9—2.1	1.5—2.2	2.0	3.9—5.3
Gizzard				1.9—2.3
Hanging tender	0.19			
Head				2.5—2.9
Head and cheek meat	0.32—0.4	0.5—0.6		
Heart	0.3—0.5	0.2—0.35	0.3—1.1	0.3—0.8
Intestines		1.8	3.3	
Kidney	0.07—0.2	0.2—0.4	0.6	
Lips	0.1			
Liver	1.0—1.5	1.1—2.4	0.9—2.2	1.6—2.3
Lungs	0.4—0.8	0.4—0.8	0.7—2.2	0.7
Pancreas	0.06	0.1	0.2	
Rennet (calf)	0.23			
Skirt	0.2—0.3	0.4—0.5	0.5	
Spinal cord	0.03			
Spleen	0.1—0.2	0.1—0.12	0.1—0.4	0.15
Sweetbread	0.03—0.05			
Heart (pancreas)	0.02			
Neck (veal)	0.02			

Tail	0.1—0.25	0.1		
Tongue	0.25—0.5	0.3—0.4		
Tripe	0.75—2.0	0.6	2.9—4.6	
Bible (omasum)	0.18			
Plain (rumen)	0.6			
Honeycomb (reticulum)	0.1			
Weasand	0.04—0.09	0.05		
Rendered edible fat	2—11	12—16	9	

Sources: Gerrard and Mallion (1977), Ockerman (1983), Romans *et al*. (1985). Ockerman and Hansen (1988, 2000).

The consumable by-products, characteristic, average weight, quantity per serving, how to store, and use in preparation are categorized in Table 4. A flow diagram of edible by-products, blood collection and processing, the percentage of the carcass, the percentage of by-products used in various countries, percentage of U.S. packers saving by- products, import and export trade of by-products, nutritional value, chemical composition of enzymatic hydrolysis of by-products, water:protein ratio, collagen and elastin content, amino acid content, cholesterol content, cooking procedures, and detailed descriptions of the by-products can be found in Chapter 1 and 2 of “Animal By-product Processing and Utilization” (Ockerman and Hansen, 2000).

Table 4. By-products consumed by humans.

By-Product	Characteristic	Average Weight, lb	Serving	Storage	Used in preparing
Blood, beef, pork, lamb					Blood food preparation, blood sausage, black pudding, blood and barley loaf, sausage ingredient
Blood plasma, pork, lamb					Sausage ingredient, Black pudding
Bone, pork, lamb, beef					Gelatin, soup, mechanically deboned tissue, rendered for shortening, refining sugar

Brains, beef, veal, pork, lamb, beef	Tender, delicate in flavor, Veal most popular	Beef – ¾-1 Lamb – ¼ Pork – ¼	¾ -1 lb for four	Frozen, thaw in hot water, Fresh, refrigerate, use in 24 hr	Used less due to BSE; separated from spinal cord; tender; Fried, broiled, sautéed, poached, braised, scrambled, creamed, cooked in liquid; liver sausage
Casings	Cattle, pigs, sheep			Used to contain sausage items	Cleaned, some layers removed and salted, Some concern over using ruminant due to BSE
Cheek and head trimmings, beef, pork, lamb					Sausage ingredient; brain (reduced use, due to BSE); stew, sauce, liver sausage; boil, poach, fry

Chitlings, chitlins, chitterlings	Small intestines of hogs, in some countries, beef is also used			Often Frozen	cleaned, simmered until tender. Served with a sauce, added to soups, battered and fried
Cracklings, pork	Crisp golden brown solid protein material from screw press or cooking after removal of lard.			Use quickly since they get rancid quickly	Used in corn bread, biscuits, muffins, added to the surface of sweet potatoes, mashed potatoes, salads, and as a snack
Ears, pork					Stewed with feet
Esophagus					Sausage ingredient
Extract, pork, lamb, beef					Soup, bouillon
Fat, oleo stock, oleo oil					Oleo-margarine, Shortening, drippings, dipping
Oleo Stearin					Shortening, sweets, chewing gum
Edible Tallow					Shortening, mincemeat, paste, pudding, dripping

Head, pork					Sausage ingredient, jelly, blood and liver sausage, pie, brown, salt and boil
Lard	Pork				Shortening, lard
Feet, pork, beef, lamb, chicken	Pig – fore shank	Pig, raw – 46% muscle	Pig feet - bone in, semi-boneless, boneless; pork hocks	Chicken eaten in orient; pig feet – fresh, frozen, cured	Jelly, cow heel, foot jelly, pickled pig feet; boil, fry, sausage
Giblets, poultry	Heart, liver, gizzard and sometime neck	Chicken -3-4 oz Liver – 2 oz Heart – 0.5 oz Gizzard – 0.1	1 pound for four	Frozen, thaw in refrigerator; Fresh, refrigerate, use in 12 hr	Fry; simmer until tender
Haggis, calves, sheep	Hearts, lungs, livers			Cooked in a sheep's stomach	Combined with oatmeal, heavy seasoning
Heart, beef, veal, pork, lamb, chicken	Beef least tender	1 beef – 4 1 veal – ½ 1 pork – ½ 1 lamb – ¼ 10-12 – chicken – 1	10-12 2-3 2-3 1 3-6 cap-on, aorta, pulmonary trunk, some of fat is removed	Frozen – thaw in refrigerator, Fresh-refrigerate use in 24 hrs.	Braise, cook in liquid, stews, fry, baked, broiled, braise, added to other meat; cavities filled with dressing and roasted; sausage, loaf patty

Intestine, large, small, pork, beef, veal, sheep					Sausage casing, pork large intestine – chitlings
Kidney, beef (loabed), veal (loabed), pork (single loabed), lamb (bean shape single loabed)	Veal, lamb and pork more tender and milder that beef; veal and lamb some times cut with loin chops	1 beef – 1 1 veal – ¾ 1 pork - ¼ 1 lamb – 1/8	4-6 3-4 1-2 0.5-1 Blood vessels, ureter, capsule, membrane, removed	Refrigerate use in 24 hours	Casseroles, stews, fry, pies; soup, wrapped in bacon and cooked on skewer, broil, fried, grill, cooked in liquid, braised, patty, loaf
Liver, beef, veal, pork. lamb, chicken	Veal, lamb, pork are more tender than beef, veal and lamb milder than pork or beef	1 beef – 10 1 veal – 2.5 1 pork – 3 1 lamb – 1 3 chicken - 1	¾ - 1 lb for 4 Gall bladder, skirt, arteries, veins, capsule fibrosa are removed	Frozen – thaw in refrigerator, Fresh-refrigerate use in 24 hrs. Grind for loafs and patties	Thin sliced braised, broiled, fry, grill, stewed, cook in liquid, fried, soups, loaves, spreads, liver sausages, patty, pate, haggis
Lung, pork, lamb					Europe – blood preparation, haggis, pet food
Meat Extract	Meat, bones extracted with boiling water or meat that is to be canned				Extracted product is condensed

Omentum, pork					Covering for processed meat, pie, pate
Oxtail, beef	Large percentage bone, disjointed, fine meat flavor		1 lb for two	Frozen, thaw in refrigerator; Fresh, refrigerate, use in 24 hr	Simmer two hours or until tender, soup, stew
Pork jowl	Pork jaw				Often cured like bacon
Processed by-product: Souse, pickled pork, headcheese, brawn, scrapple	High collagen meat such as whole pigs head including tongue, trotters, snouts, ears, skin			Sometimes stuffed into casings and cold smoked, very perishable	Boil and simmer until tender, season, remove the meat, cool to jell
Skin trimmings, skeens; pork, beef				Pork rinds can be stored for 6 months at room temperature	Rind emulsion for sausage, gelatin, jellied food, pork rinds; Extract collagen for extrusion into casings
Skirt, thick, pork, beef					Stew, sausage ingredients

Spleen, pork, lamb					Blood sausage, pie; fry, flavoring, melt, variety meat
Stock, soup, Beef, veal, lamb, pork	Bones, meat scraps			Refrigerate or frozen	Roasted with vegetables, simmered, strained, cooled. Used in dishes, soups sauces, gravies
Sweetbreads, beef, veal, lamb	From the heart and throat (thymus) – fat rich, only in young animals, gut (pancreas) bread	Veal, neck and heart pair -1 Beef, neck only – 1/8 Beef heart-bread – 0.15 Beef Gut bread - 3/8 Lamb – 2 oz. Lamb gut – 3/16 Pig gut – 3/16	¾ - 1 lb for four	Frozen, thaw in hot water, Fresh, refrigerate, use in 24 hr	Tender and delicate flavor; membrane, lymph nodes, vessels removed; breaded deep fat fry, coated with butter broil, braise, cook in liquid, stew, poach, scrambled with eggs, cream, variety meat
Stomach, pork					Sausage ingredient; sausage container, precook in water, braise, fry, boil

Tail, lamb				Clean and freeze till needed	Bread and fry
Tail, pork		1.5	4 per serving	Sometimes cured and smoked	Hotchpot; Barbecued, salt and boil, used with sauerkraut, mustard greens beans
Testicles. lamb, Rocky Mountain oysters, lamb fries; other species are also used			1 per serving		Boil until tender, simmer; Bread and fry, grill
Tongue, beef, veal, pork, lamb	Fat rich, types; square cut, short cut, Swiss cut, long cut	1 beef 3-4 1 veal 1-2 1 pork ¾ 1 lamb – ½	12-16 3-6 2-4 2-3 Amount of trimming varies with type of cut	Fresh-refrigerate use in 24 hrs. pickled soak before cooking	Fresh - thin slice, long term moist heat, broil, stew, smoked, pickled, jellied, potted, canned, blood and liver tongue sausage

Tripe, beef, sheep, pork stomach	Beef, Honeycomb (preferred), Plain, Bible, hard to clean and usually not used, calf – rennet	Beef, Honeycomb – 1.5, Plain – 7, Sheep – 2.2	Plain ¾ - 1 for 4	Fresh, refrigerate, use in 24 hrs. pickled, soak before use, canned, heat and serve	Often pre cooked but requires further cooking; sausage ingredient; lamb - container for haggis
Udder					Eaten in Europe; boil, salt, smoke, fry

Sources: Ockerman and Hansen; 1988, 2000, Fornias, 1996; McLean and Campbell, 1952; National LiveStock and Meat Board, 1974 a,b; Ockerman 1975, 1996

Another edible by-product is gelatin. Gelatin and glue are both water-soluble, hydrophilic, derived colloidal proteins (albuminoids) produced by controlled hydrolysis of water-insoluble collagen (white fibrous connective tissue). Gelatin and glue are physically and chemically similar but gelatin is made from fresh, federally (in the U.S.) inspected raw materials which allows it to remain in the edible category. Since collagen is 30% of the body's total organic matter or 60% of the body protein, gelatin can be extracted from many raw materials. This pure protein from collagen (hides, pig skins, bones, ossein, and isinglass) is used in ice cream, mayonnaise dressing, emulsion flavors, to clarify wine, beer and vinegar, and is used to make capsules and coating for pills. Collagen (anhydride of gelatin) is constructed of tropocollagen monomers arranged in overlapping fibrils that are configured in three nonidentical, coiled peptide chains with molecular weight ranging from 40,000 to 100,000 (Etherington and Roberts, 1997). The number and type of covalent cross-bonds between chains are altered as the animal ages (more abundant in older animals) and this influences the properties of the extracted gelatin. The conversion of tropocollagen to gelatin requires breaking of hydrogen bonds which unstabilizes the triple-coil helix and converts it into a random coil configuration of gelatin which is stabilized by the cross-links that remain and the aminoterminal and carboxylterminal groups that have been formed. Since the three original chains were not identical, it results in a single gelatin sample with several molecular weights. The alpha-chain contains one peptide chain, the beta-chain with two connected peptide chains, and the gamma chain made up of three peptide chains. The distribution of the molecular weights determines the functionality of the gelatin. Larger concentrations of low molecular weight molecules will lower viscosity and gel strengths. This condition is usually caused by high temperatures, high acidic or alkaline conditions, type of raw material, or liming time. Nutritionally, gelatin is a long chain of both acidic and basic amino acids connected by peptide bonds. It is high in glycene and lysine but low in tryptophan and methionine. This makes it a non-complete protein since it does not supply the daily requirement of “essential” (amino acids that can not be synthesized by the body) amino acids. However, in a “normal diet” with other proteins, it can be quite nutritionally useful. Gelatin has a high content of the amino acids proline and hydroxyproline and the quantities of amino acids are often used as an index of the quantity of gelatine in a protein mix.

The extraction of gelatin is performed in four stages:

1. Selection of appropriate raw materials which can influence the characteristic of the gelatin.
2. Removal of non collagenous compounds from the raw material with as little change in collagen as possible.

3. Controlled hydrolysis of collagen to gelatin.

4. The recovery and drying of gelatin.

There are also three processes to obtain gelatin from collagen and also various combinations of these procedures.

1. **Alkaline procedure (Type B gelatin).** The most common procedure consists of washing, followed by saturated calcium hydroxide (liming period) which causes the noncollagen material to become more soluble and can be removed by later washing. Liming also causes hydrolytic reactions with limited solubilization. Next the pH is lowered and the lime is washed with cold water and removed from the stock. This is followed by washing with dilute acid and a final wash with sulphate. The stock is now placed in extraction kettles and extraction takes place in a series of cooks. The liquid extract is pressure filtered followed by evaporation.
2. **Acid procedure (Type A gelatin).** This procedure is often used with pigskins and bones. The raw material is first washed and fat is often preextracted (with heat or nonpolar chemicals). The raw material is then soaked in inorganic acids, followed by a wash to raise the pH. Next, the collagen is given an alkaline treatment. It is then filtered and dried. The product is now subjected to a series of cooks and then quickly dried. The acid and alkaline procedures produce two different classes of gelatin and the products produced are not interchangeable.

3. **High pressure steam extraction.** Gelatin is used at fairly low levels (1-2.5%) in gelatin desserts. More details on gelatin extraction, amino acid content, potential raw materials, yield, flow charts, and preservatives can be found in Chapter 5 of the book "Animal By-product Processing and Utilization" (Ockerman and Hansen, 2000).

Edible tissue from bone

Bones have long been used to make soup and gelatin. As labor becomes more expensive and as the animal processing industry has attempted to salvage more of adhering meat from bones, new separating techniques have been developed. With the conventional processing of fish, large quantities of edible tissue is lost and trash fish is usually discarded due to its boney nature. At the same time, specialty items can utilize the non-whole muscle meat products that were developed. In the poultry industry, the trend from marketing whole birds to parts, left a number of parts difficult to merchandise and spent layers were also a source of available material. Again, specialty products were being developed that can use extracted tissue. In the beef industry, carcasses were being replaced by boxed beef (wholesale curs) which concentrated large quantities of bones in a few locations. All of this makes mechanically deboning more practical. This process can return major quantities of edible tissue back into the market place.

The terms mechanically separated meat (MSM) and mechanically separated poultry (MSP) are used in the U.S. The term mechanically recovered meat is sometimes used in Europe. Minced fish is used for mechanically deboned fish. Large quantities of mechanically deboned poultry are currently being used in the U.S. with smaller quantities of red meat being utilized.

Excellent early reviews by Field (1981, 1988), and Froning (1981) can add considerable insight to this process. History, U.S. regulations, yield, composition, nutrients, protein efficiency ratio (PER), flow charts, and equipment is reported by Ockerman and Hansen (2000).

In general, the bones and tissue is finely ground and the soft tissue is forced through small (0.5mm) orifices. The resulting structure of the pressed material is finely ground, and paste-like in which the myofibrils are heavily fragmented. Post-pressed treatments range from no treatment, washed and dewatered, high temperature, centrifugation, and using emulsion additives. Selection of the size of the orifices and the amount of pressure applied can affect the yield, the amount of bone marrow, and the size and amount of bone powder in the finished product.

Microbiological quality is determined by quality of raw bones which is determined by sanitary handling, low temperatures and limited storage, and ratio of external tissue to internal tissue. Temperature rise during deboning and find grinding also contributes to an ideal environment for bacterial growth. Rapid lowering of temperature and controlling time after deboning is also critical.

Rancidity can also cause problems in this tissue. Since bone marrow has more unsaturated fat, temperature is higher due to deboning and more mixing occurs, and more incorporation of air and heme pigments, than hand deboning which causes oxidation to be a major concern. Even though oxidation is reduced at low temperature, it can still continue even in frozen deboned meat.

The additional bright red color is considered a plus for some processed meat items but is a negative if a pale product is desired.

Other properties such as emulsifying capacity, water holding capacity and emulsion stability is comparable to a hand deboned product.

The addition of bone marrow causes a rise in pH which aids water holding capacity and emulsion formation.

Negatives would include elevated calcium (however U.S. diet is usually low in calcium) and magnesium.

Uses of this separated product include incorporation into sausage-type products, stews, sauces, spreads and even in chunked and formed products. Also, the favorable price compared to hand deboned tissue makes this a favorite for least cost products.

Other extraction methods include liquid extraction, and cold alkaline extraction. Flavor extraction material is obtained by heating in liquid acid or with centrifugal cooking.

Medical and pharmaceutical uses of by-products are other uses for the non-carcass portion of the animal that are directly utilized by humans. These include animal glands, arteries, bezoars, bile, blood, bone, brain, duodenum, eggshell powder, feather, gall bladder, glycosaminoglycans, hair, heart, horns, intestines, liver, lungs, nervous systems, ovaries, oyster shell, pancreas, serum, skin, spinal cord, spleen, stomach, etc. Miniature hogs are also used in medical research since many of their systems are similar to humans. These medical and pharmaceutical uses are discussed in detail in Chapter 7 of "Animal By-product Processing and Utilization (Ockerman and Hansen, 2000).

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